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Review of the tropical Southeast Asian *Ephemera* (Ephemeroptera: Ephemeridae)

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The genus *Ephemera* Linnaeus, the type genus of the family Ephemeridae and the order Ephemeroptera, began to be studied as early as in the nineteenth century, but the East Asian species of *Ephemera* remained poorly understood. In this paper, 16 *Ephemera* species from tropical Southeast Asia are reviewed and descriptions of new or poorly known species and life stages, synonyms, reference sources, type information, taxonomic remarks, a male adult key to the species, and a tabulated checklist of the species are provided. *Ephemera mccaffertyi* sp. n. from Malaysia is described. *Ephemera hainanensis* Zhang, Gui & You, *E. rufomaculata* Zhou & Zheng, and *E. pilosa* Navás are redescribed. The larval stage of *E. hainanensis* and *E. pilosa* are described. *Ephemera innotata* Navás, *E. javana* Navás, *E. longiventris* Navás, and *E. quadrigutata* Lestage are assigned as *nomina dubia*. As a result of this study, four species from Vietnam, four species from Myanmar, two species from Thailand, one new species from Malaysia, and three species from Taiwan have been identified as members of the genus *Ephemera*.

Keywords: *Ephemera mccaffertyi* sp. n.; taxonomy; burrowing mayflies; Ephemeroidea; tropical streams

Introduction

The burrowing mayfly family Ephemeridae is generally cosmopolitan in its distribution, and members have been recorded on every continent, except in Australia and oceanic islands. Although members of this family have been treated relatively frequently in taxonomic and ecological studies due to their large body size, common occurrence, and ecological importance in freshwater environments, they remain poorly understood in tropical Southeast Asia.

The genus *Ephemera* Linnaeus, the type genus of the Ephemeridae and Ephemeroptera, contains 68 species worldwide, and this genus comprises approximately 71% of the known species of Ephemeridae (Hwang, Bae and McCafferty 2007). Although the largest number of *Ephemera* species (34 species) have been identified in the combined area of southern China and Southeast Asia, the majority of members of this genus (30 species) have been recorded in southern China, whereas 12 species were described in the nineteenth and early twentieth centuries in tropical Southeast Asia,

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including both peninsular and insular Southeast Asian countries (Table 1): *Ephemera exspectans* (Walker) (1860), *E. serica* Eaton (1871), *E. pulcherrima* Eaton (1892), *E. sauteri* Ulmer (1912), *E. longiventris* Navás (1917), *E. formosana* Ulmer (1919), *E. purpurata* Ulmer (1919), *E. duporti* Lestage (1921), *E. immotata* Navás (1922), *E. quadriguttata* Lestage (1927), *E. javana* Navás (1930), and *E. annandalei* Chopra (in Hafiz 1937). Hsu (1936–1937b), Ulmer (1926), Uéno (1969), and Kang and Yang (1994) additionally dealt with Southeast Asian *Ephemera* species.

Since the descriptions and type information regarding the East Asian *Ephemera* species described in the middle to late nineteenth and early twentieth centuries exist only in fragmentary form and are less informative, the majority of the species were poorly defined, and have thus been historically confused. In particular, the species group characterised by multiple abdominal stripes constitutes a serious taxonomic problem. The descriptions of *Ephemera* species described in mainland China in the second half of the twentieth century (e.g. You and Gui 1995) intensified these taxonomic confusions, because descriptions of the Chinese species have not been comparatively conducted with aforementioned species.

In this study, on the basis of currently available material and bibliographic sources, all previously characterised species of tropical Southeast Asian *Ephemera* have been reviewed and descriptions and redescrptions of newly and poorly known species are provided. As a result of this study, a total of 16 *Ephemera* species are recognised to exist in tropical Southeast Asia. These 16 species include one new species and three new records, and exclude four *nomina dubia* species (see Table 1).

Materials and methods

Larval and adult materials from various areas of East Asia housed in the Aquatic Insect Collection of Seoul Women's University (SWU-AIC), the Entomological Research Collection of Purdue University (PERC), Nanjing Normal University (NJNU), and Hanoi University of Science (HUS) were examined in this study. Type information regarding the species known in Southeast Asia was acquired from the British Museum of Natural History (BMNH) in London, the Swedish Museum of Natural History (SMNH) in Stockholm, the Musee Heude in Shanghai (MHS) and the National Museum of Natural History in Paris (PMNH) in Paris. The following reference sources were employed in order to obtain additional type information: Kimmins (1960) and Hubbard and Peters (1978) for the types housed in the BMNH, Hubbard and Peters (1978) and Hubbard and Srivastava (1984) for the types in the Zoological Survey of India (ZSI) in Calcutta, and Alba-Tercedor and Peters (1985) for the types in the Museo de Zoología del Ayuntamiento in Barcelona (MZA). In addition, we have personally consulted mayfly taxonomists (see Acknowledgements) regarding the type information of the Southeast Asian *Ephemera* species.

The following abbreviations refer to the life stages of mayfly materials: M (male adult), F (female adult), MS (male subimago), FS (female subimago), and L (larva).

Taxonomy

Ephemera annandalei Chopra, 1937

Ephemera annandalei Chopra, 1937 (in Hafiz 1937: 360; M, MS, F) [Holotype stage: MS; Holotype locality: Shillong, India; Holotype deposition: ZSI]; Hubbard & Peters, 1978: 15 (catalogue); Hubbard & Srivastava, 1984: 1 (type information).

Table 1. Checklist of the tropical Southeast Asian *Ephemera* species.

No	Species	Original description (life stage/locality)	Type deposition	Secondary sources	Distribution	Remarks
1	<i>E. amandalei</i>	Chopra (1937) (in Hafiz 1937) (M, F, MS/India: Shillong)	ZSI	Hubbard and Peters (1978) (catalogue)	India, Myanmar	Type deposition confirmed by Hubbard and Srivastava (1984)
2	<i>E. duporti</i>	Lestage (1921) (M, F, MS, FS/Tonkin)	MZA (Holotype of <i>Nirvius punctatus</i> Navás)	Navás (1922) (<i>N. punctatus</i> : M/Myanmar)	Myanmar, Tonkin	Synonymised by Lestage (1922); Type (<i>N. punctatus</i>) deposition confirmed by Alba-Tercedor and Peters (1985)
3	<i>E. exspectans</i>	Walker (1860) (FS/India: Hindostan)	BMNH	Hafiz (1937) (M/India, Myanmar)	India, Myanmar	Type deposition confirmed this study
4	<i>E. formosana</i>	Ulmer (1919) (M, F/Taiwan)	DEI	Kang and Yang (1994) (L/Taiwan)	Mainland China, Japan, Taiwan	Japanese distribution confirmed this study
5	<i>E. hainanensis</i>	Zhang et al. (1995) (M, F/China: Hainan)	NJNU	Not present	Hainan (China), Taiwan, Vietnam	Taiwanese and Vietnamese distribution confirmed this study; Larva described this study
6	<i>E. innotata</i>	Navás (1922) (M/Tonkin)	No type information	Not present	Tonkin	<i>nomen dubium</i>
7	<i>E. javana</i>	Navás (1930) (F/Indonesia: Java)	SMNH (Type not exist)	Uéno (1969) (M/Thailand, Indonesia: Java, Sumatra)	Indonesia	<i>nomen dubium</i> (see Remarks under <i>E. rufomaculata</i>)
8	<i>E. longiventris</i>	Navás (1917) (F/Vietnam)	No type information	Lestage (1921) (locality information)	Vietnam	<i>nomen dubium</i>
9	<i>E. mccaffertyi</i>	This study (M, F/Malaysia)	PERC		Malaysia	Newly described this study
10	<i>E. pulcherrima</i>	Eaton (1892) (FS/Myanmar: Tenasserim valley)	BMNH	Hsu (1936–1937b) (M, F/China)	China, Myanmar	Type deposition confirmed this study

(continued)

Table 1. (Continued).

No	Species	Original description (life stage/locality)	Type deposition	Secondary sources	Distribution	Remarks
11	<i>E. purpurata</i>	Ulmer (1919) (M, MS/China: Kouy-Toheou)	PM	Uéno (1969) (F/China, Thailand)	China, Thailand	Type preservation unknown
12	<i>E. quadriguttata</i>	Lestage (1927) (M/Vietnam)	No type information	Not present	Vietnam	<i>nomen dubium</i>
13	<i>E. rufomaculata</i>	Zhou (2003) (M, F, L/China)	NJNU	Not present	China, Thailand	Larva redescribed this study
14	<i>E. sauteri</i>	Ulmer (1912) (M, F, FS/ Taiwan: Kosempo)	ZSI	Kang and Yang (1994) (L)	Mainland China, Taiwan	Type deposition confirmed by Hubbard and Srivastava (1984)
15	<i>E. serica</i>	Eaton (1871) (M, F/China)	BMNH	Ulmer, 1926 (M, F, MS, FS/China Vietnam)	China, Tonkin	Type deposition confirmed this study
16	<i>E. pilosa</i>	Navás (M, F/China)	SWU-AIC	Hsu, 1937–1938 (M, F/China)	China, Vietnam	Vietnamese distribution confirmed this study; Larva described this study

Material. Holotype (confirmed by Hubbard and Srivastava 1984). MS, ZSI no. 967/H8 (on 4 slides), Shillong, India, [ZSI].

Diagnosis. The male adult of *E. annandalei* can be characterised by the body length (13 mm), hind coxae with one blackish spot, abdominal terga III–IX with three pairs of longitudinal black stripes, and short, triangular, and apically slightly round penes (modified from Chopra 1937).

Distribution. India (Shillong), Myanmar (Namkhai River, Kutkai, North Shan State).

Remarks

Ephemera annandalei was originally described from Shillong (Assam), India, at an altitude of 4500 ft, by Chopra in Hafiz (1937) based on male subimaginal and female adult specimens. Hafiz (1937) additionally described the male adult of this species from Harai, Rewa State, India, and recorded its female adults from Myanmar. The type and other specimens deposited at the ZSI were later examined by Hubbard & Srivastava (1984). The general body colour of *E. annandalei* is similar to that of *E. exspectans* (Walker), but the stripes of the abdominal terga are not chocolate, but clove brown to blackish brown. Hafiz (1937) provided the male adult abdomen, forewing, hind wing, and genital figures of *E. annandalei*.

Ephemera duporti Lestage, 1921

Ephemera duporti Lestage, 1921: 216 (M, F, MS, FS) [Syntypes: M, F, MS, FS; Tonkin; Type deposition unknown].

Nirvius punctatus Navás, 1922: 56 (M) [Holotype: M; Pakang, Myanmar; MZA]; Alba-Tercedor & Peters, 1985: 222 (type information).

Ephemera punctatus (Navás): Lestage, 1922: 253 (generic combination and synonymy).

Material. Holotype of *Nirvius punctatus* Navás, 1922 (confirmed by Alba-Tercedor & Peters 1985). M, Pakang, Indochina, 28-XI-1918, [MZA].

Diagnosis. The male adult of this species can be characterised by the body length (10–12 mm) and abdominal terga, which evidence three pairs of black longitudinal stripes on abdominal terga II–VI, two pairs of black longitudinal stripes on abdominal terga VII–VIII, and brown markings on abdominal terga IX–X (modified from Lestage 1921).

Distribution. Myanmar (Pakang), Tonkin.

Remarks

Ephemera duporti was originally described by Lestage (1921) based on male and female adult and subimaginal specimens collected in the Tonkin area. Navás (1922) described *Nirvius punctatus* based on a male adult specimen collected in Pakang, Myanmar. Shortly after, Lestage transferred *Nirvius punctatus* to *Ephemera* and synonymised it with *E. duporti* Lestage (1921). According to Alba-Tercedor and Peters (1985), the male adult holotype specimen of *Nirvius punctatus* Navás was deposited at the MZA, but it possesses no caudal filaments.

***Ephemera expectans* (Walker, 1860)**

Potamanthus expectans Walker, 1860: 198 (FS) [Holotype: FS; Hindostan, India; BMNH].

Ephemera expectans (Walker): Eaton, 1871: 74 (FS); Kimmins, 1960: 308 (type information); Hubbard & Peters 1978: 16 (catalogue).

Ephemera expectans (Walker): Eaton, 1883–88: 72 (FS); Lestage, 1927: 95 (key); Hafiz, 1937: 366 (M).

Ephemera vedana Banks, 1913: 137 (subimago: Chapra, Bengal, India); Ulmer, 1920: 109 (list); Lestage, 1927: 95 (key). (synonymised by Hafiz 1937).

Material. *Holotype* (confirmed by Hubbard & Peters 1978 and D. Goodger, personal communication): FS, Saunders 68-3, Hindostan, India, [BMNH].

Diagnosis. The male adult of this species can be characterised by the body length (13.5 mm) and two pairs of slender longitudinal black stripes on abdominal terga II–VIII (modified from Hafiz 1937).

Distribution. India (Hindostan), Myanmar.

Remarks

This species was originally described by Walker (1860) as *Potamanthus expectans* Walker based on the female subimaginal specimen collected in India. Eaton (1871) transferred this species to the genus *Ephemera*. Hafiz (1937) recorded a male adult from Naukuchia Tal, Kumaon Hills, Uttarakhand, India and female adults from Chaungwa, Myanmar. According to Hafiz (1937), five male specimens from Mysore were deposited at the Government Museum (currently Madras Museum) in Chennai, India; and according to Hubbard and Peters (1978) and D. Goodger (personal communication), Walker's type specimen is housed in the BMNH.

Banks (1913) described *Ephemera vedana* based on a subimaginal specimen, but its additional type information remains unknown. Hafiz (1937) and Hubbard and Peters (1978) listed *E. vedana* as a synonym of *E. expectans* (Walker). Although Bank's description of *E. vedana* contains limited diagnostic characters, we follow this synonymy as both of the species were described from a local area (Bihar) in northern India. Hubbard and Peters (1978) erroneously cited this species as *Ephemera vedans*.

The *Ephemera* species in East Asia with paired multi-stripped markings on the abdominal terga have been historically confused (Hwang, Lee and Bae 2003). Although Hafiz (1937) provided some diagnostic characters of *E. expectans* (Walker), e.g. abdominal stripes, more deterministic characters, such as genital structures, must be described using fresh materials from the type locality in order to correctly characterise *E. expectans* and other related species. No figures were provided by the authors who described this species.

***Ephemera formosana* Ulmer, 1919**

Ephemera formosana Ulmer, 1919: 6 (M, F, MS, FS) [Syntypes: M, F, MS, FS; Taiwan; DEI]; Hsu, 1936–1937a: 147 (M, F); Kang & Yang, 1994: 394 (L); Ishiwata & Takemon, 2005: 48 (key).

Material. 1M & 1F: Nishi-Funatsuki-Gawa River, Taketomi (Iriomote Island), Okinawa Prefecture, Japan, 12-V-1999.

Diagnosis. Male and female adults and larva of this species can be characterised by the body size (14–16 mm), hind coxae with one blackish spot, forewings and hind wings without markings, and three pairs of longitudinal black stripes on abdominal terga VII–IX.

Distribution. China (Guangdong, Taiwan), Japan (Ryukyu Islands).

Remarks

Ulmer (1919) described *E. formosana* based on male and female adult and subimaginal specimens collected in Taiwan (Formosa). Later, Ulmer (1926) recorded this species from Guangdong, China. Uéno (1969) recorded this species from the Ryukyu Islands (Ishigaki and Okinawa), Japan, and from Urai, Taiwan. Kang and Yang (1994) described the larval stage for the first time using material collected in Taiwan. Ulmer's syntype specimens were deposited at the DEI (Ulmer 1919, 1926; Hsu 1936–1937a) and Kang and Yang's (1994) larval specimens were deposited at the National Chung Hsing University in Taichung, Taiwan.

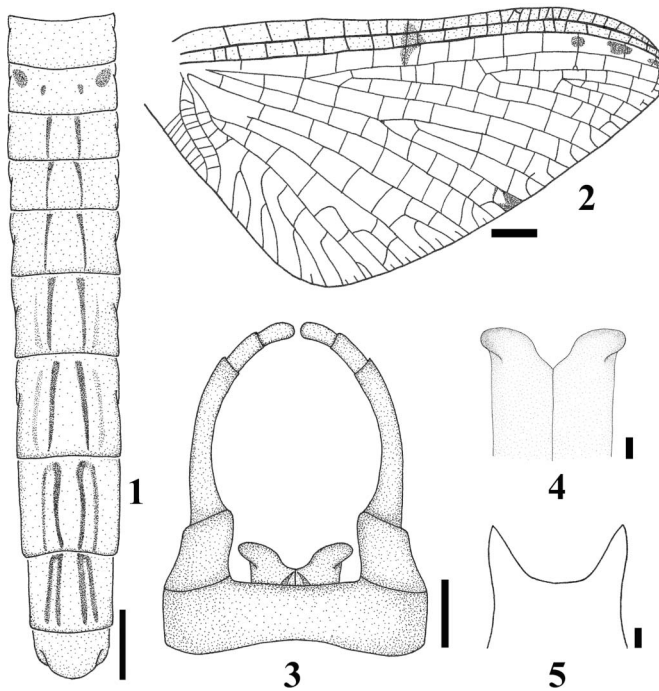
The adults of *E. formosana* generally resemble those of *E. orientalis* McLachlan (1875) and *E. sauteri* Ulmer (1912), but they can be distinguished from each other by the shape of penes as well as by the absence of the blackish spot on the hind coxae in *E. orientalis* and the presence of the three pairs of longitudinal stripes on abdominal terga III–IV in *E. sauteri*. Ulmer (1919) provided the figure of the male adult abdominal markings. Ishiwata and Takemon (2005) provided the figures of the male adult abdomen and genitalia. Kang and Yang (1994) provided the figures of the larval head, mouthparts, pronotum, and abdomen. Based on comprehensive examinations of the Taiwanese material consisting of the adults, larvae, and eggs of *E. formosana* and *E. sauteri*, Kang & Yang (1994) detected some minor characters by which these two species could be distinguished, but the characters are not fundamental. According to Kang and Yang (1994) and Ueno (1969), the larvae of *E. sauteri* inhabit high mountain streams, approximately 2200 m in altitude, whereas those of *E. formosana* occur at altitudes below 1000 m.

Ephemera hainanensis Zhang et al. 1995 (Figures 1–5)

Ephemera hainanensis Zhang et al. 1995; 71 (M, F, MS) [Syntypes: M, F, MS; Hainan, China; NJNU]; You & Gui, 1995: 99 (M, F).

Material. Vietnam: 11 M, 3 MS & 2 F, BaNa-Nui Chua, Tuy Loan Creek, Suoi An Loi 200 m, Da Nang Prov., light trap, 1-IV-2002, DH Hoang & V.V. Ngyuen; 1 F, Con Cuong, Khe Choang Creek, Nghe An Prov., 6-IV-2002, D.H. Hoang & V.V. Ngyuen; 6 F, Rao Mai, Hurong Son Ha Tinh Prov., 9-V-2004; 21 MS & 15 L, Thua Thien Hue, Nam Dong, Khe Tre Br., light trap, 22-IV-2006, J.M. Hwang & D.G. Kim [SWU-AIC]; Taiwan: 23 MS, Taipei, 21~27-VII-1966 [PERC].

Diagnosis. The adult of this species can be characterised by the hind coxae with three blackish spots, abdominal terga (Figure 1) III–V with one pair of longitudinal dark brown stripes, and abdominal terga VI–IX with two pairs of longitudinal stripes; in male, by U-shaped and apically blunt penes (Figures 3, 4). The larva can be characterised by the abdominal stripes similar to that of adults.



Figures 1–5. *Ephemera hainanensis*, male adult: (1) abdomen; (2) forewing; (3) genitalia; (4) penis. Larva: (5) frontal process. Scale bars = 1 mm (1, 2, 3), 0.1 mm (4, 5).

Male adult. Body length 13.9–15.6 mm, caudal filaments 27.6 mm. Body colour pale yellow with various brown markings.

Head. Compound eyes dorsal part grey and ventral part dark grey in alcohol; ocelli dorsal half white and basal half black; antenna with pedicel light yellow and apically dark brown; flagellum pale yellow.

Thorax. Pronotum pale yellow, medially with one pair of nearly oval-shaped brown stripes; stripes not reaching to anterior and posterior margins. Mesonotum pale yellow with one pair of irregular brown markings. Metanotum pale yellow. Forelegs pale yellow; femur, tibiae, and tarsi darker at joints; claws darker apically; femur 1.59 mm, tibia 3.86 mm, and tarsus 5.23 mm (segments 1, 2, 3, and 4 1.89 mm, 1.51 mm, 1.21 mm, and 0.62 mm, respectively); claws similar. Midlegs and hind legs pale yellow; hind coxae with three spots; claws dissimilar. Forewings (Figure 2) 5.7 mm in length, 11.2 mm in width; apical area with three or four dark brown round markings. Hind wings 2.9 mm in length, 4.5 mm in width, without markings.

Abdomen. Abdominal terga (Figure 1) pale yellow; tergum I without marking; tergum II with one pair of short dark brown stripes and with dark brown round spots laterally; terga III–V with one pair of longitudinal dark brown stripes; terga VI–IX with two pairs of longitudinal dark brown stripes (outer stripes lighter in colour); terga II–IX with dark spots at lateral margins. Abdominal sterna pale yellow; sterna II–IX with one pair of dark brown longitudinal stripes; stripes on sternum IX relatively broader and shorter than other stripes.

Genitalia (Figures 3 and 4). Genital forceps pale yellow, four-segmented; subgenital plate nearly straight; penis (Figure 4) paired, U-shaped in median margin, apically blunt. Caudal filaments pale yellow, with brown annulations at articulations.

Female adult. Body length 10.8–15.4 mm, caudal filaments 15.9 mm. Colouration and markings similar to male adult.

Mature larva. Body length 12.3–13.0 mm; caudal filaments 4.1–4.4 mm.

Head. Compound eyes black. Pedicel of antennae with two heavily stout setae ventrally near distal margin; antennal flagellum with well-developed whorls of hairlike setae. Head frontal process (Figure 5) deeply concave, apicolaterally acute; lateral margins slightly curvy; dorsal surface with long setae. Labrum anterior margin emarginated. Mandibular tusks well-developed. Maxillary palpi three-segmented; segments 2 and 3 with long setae. Labial palpi three-segmented, terminal segment with stout setae.

Thorax. Pronotum yellowish brown, with dense setae on anterolateral and lateral margins; mesonotum light yellow. Legs brown; hind coxae with three blackish spots.

Abdomen. Abdomen yellowish brown, with brown markings; abdominal terga and sterna colour pattern similar to male adult. Caudal filaments with row of lateral hairlike setae.

Distribution. China (Hainan, Taiwan), Vietnam.

Remarks

Ephemera hainanensis was described by Zhang, Gui and You (1995) on the basis of the male and female adult specimens collected from Hainan, China. As the original description of this species was written in Chinese, we have re-described this species in English. We describe the larval stage for the first time in this study using material obtained from Vietnam. The description in You and Gui (1995) is a reproduction of the original description by Zhang et al. (1995) which is also based on the manuscript of Zhang's Master's thesis (unpublished). Zhang et al. (1995) is, therefore, the official publication for this species authorship.

Ephemera innotata Navás, *nomen dubium*

Ephemera innotata Navás, 1922: 54 (M) [Type: M; Tonkin, Indochina; Type deposition: Unknown].

Material. Not available.

Distribution. Indochina Peninsula (Tonkin).

Remarks

This species was described by Navás (1922) based on the male adult specimen collected from the Tonkin area in the Indochinese Peninsula. Navás' (1922) original description, however, does not contain characters by which the identification of this species can be verified nor does it specify the depository of the type specimen. Currently known

bibliographic sources dealing with Navás' type material (e.g. Alba-Tercedor and Peters 1985; Hubbard 1991) do not include this species.

Ephemera javana* Navás, *nomen dubium

Ephemera javana Navás, 1930: 432 (F) [Type: F; Java: Soekabani, Le Moults; SMNH]; Uéno, 1969: 233 (M).

Material. Not available.

Distribution. Java, Sumatra, Thailand.

Remarks

Ephemera javana was originally described by Navás (1930) on the basis of the female adult specimen collected from Java, Indonesia. Navás' (1930) original description, however, does not contain characters by which the identification of this species can be verified. Navás (1930) indicated that the type specimen of this species is deposited at the Stockholm Museum, currently the Swedish Museum of Natural History (SMNH), in Sweden, but the type specimen does not exist in the Ephemeroptera collection in this museum (M. Svensson, personal communication). Uéno (1969) described the male adult stage of *E. javana* Navás from specimens collected from the Mae Sa waterfall in northern Thailand, but we were unable to verify his identification. Uéno's male adult specimen may belong to *E. rufomaculata* Zhou & Zheng (see Remarks under *E. rufomaculata*, below).

Ephemera longiventris* Navás, *nomen dubium

Ephemera longiventris Navás, 1917: 9 (F) [Type: F; Hanoi (Tonkin), Vietnam; Type deposition: Unknown]; Lestage, 1921: 216 (distribution).

Material. Not available.

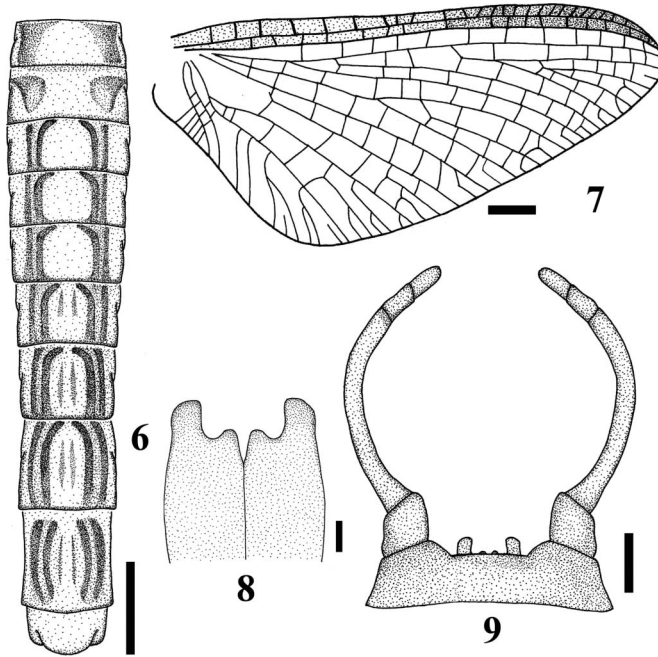
Distribution. Vietnam.

Remarks

Ephemera longiventris was originally described by Navás (1917) on the basis of the male adult specimen collected from Hanoi, Vietnam. Navás' (1917) original description, however, does not contain characters by which the identification of this species can be verified, nor does it specify the depository of the type specimen. Currently known bibliographic sources dealing with Navás' type material (e.g. Alba-Tercedor and Peters 1985; Hubbard 1991) do not include this species. Currently, few natural habitats for *Ephemera* larvae exist in the Hanoi area, as the result of urbanisation (V.V. Nguyen, personal communication). Therefore, the capture of topotype material is unlikely to occur.

***Ephemera mccaffertyi* sp. n. (Figures 6–9)**

Material. Holotype. M (penes dissected), Selangor large Trib., Sungai Selangor, 6 mi., NE Kota Kuba Baharu, Malaysia, 1-IX-1978, GF & CH Edmunds, PERC. Paratype: 1 FS, same data as holotype.



Figures 6–9. *Ephemera mccaffertyi* sp. n., male adult: (6) abdomen; (7) forewing; (8) penis; (9) genitalia. Scale bars = 1 mm (6, 7, 9), 0.1 mm (8).

Diagnosis. The male adult of this species can be characterised by the body length (12.3 mm), hind coxae with two blackish spots, abdominal terga III–V (Figure 6) with two pairs of longitudinal dark brown stripes, abdominal terga VI–IX with three pairs of longitudinal dark brown stripes, and medially notched and apically blunt penes (Figures 8, 9), which are also reduced only to a visible apical part.

Male adult. Body length 12.3 mm, caudal filaments broken. Body colour pale yellow, with various brown markings.

Head. Compound eyes dark grey in alcohol; ocelli dorsal half white and basal half black. Antennae 1.0 mm, pale yellow.

Thorax. Pronotum pale yellow, medially with one pair of longitudinal broad dark brown stripes. Mesonotum pale yellow, with paired various brown markings. Metanotum pale yellow. Forelegs pale yellow; foretibiae and foretarsi darker at joints; foreclaws darker apically; forefemur 1.30 mm, foretibia 3.95 mm, and foretarsus 3.95 mm (segments 1, 2, 3, and 4 0.91 mm, 0.67 mm, 1.31 mm, 1.06 mm, respectively); foreclaws similar. Midlegs and hind legs pale yellow; hind coxae with two blackish spots; midclaws and hind claws dissimilar. Forewings (Figure 7) 6.4 mm in length, 10.9 mm in width, with dark brown costal and subcostal areas. Hind wings 2.4 mm in length, 4.2 mm in width, without markings.

Abdomen. Abdominal terga (Figure 6) pale yellow; tergum I laterally darker; tergum II with brown markings laterally; terga III–V with two pairs of longitudinal dark brown

stripes; terga VI–IX with three pairs of longitudinal dark brown stripes; median pair of stripes on tergum VI relatively short and pale; terga II–IX with dark spots on lateral margins. Abdominal sterna pale yellow; sterna II–IX with one pair of dark brown longitudinal stripes; stripes on sternum IX relatively broad.

Genitalia (Figures 8 and 9). Genital forceps pale yellow, four-segmented; subgenital plate nearly straight; penis (Figure 8) only apically visible, notched medially, apically blunt. Caudal filaments pale yellow, with brown annulations at articulations.

Female subimago. Body length 16.5 mm, caudal filaments dried, terminally broken. Colour and markings similar to male adult.

Etymology. The specific epithet, *mccaffertyi*, is derived from the name of Prof. W.P. McCafferty of Purdue University in honour of his great contributions to Ephemeroptera systematics.

Distribution. West Malaysia.

***Ephemera pulcherrima* Eaton, 1892**

Ephemera pulcherrima Eaton, 1892: 185 (FS) [Holotype: FS; Tenasserim Valley, Myanmar; BMNH]; Ulmer 1926: 86 (M); Hsu, 1936–1937b: 433 (M, F); Hubbard & Peters, 1978: 17 (catalogue); Kimmins, 1960: 308 (type information).

Material. Holotype (confirmed by D. Goodger, personal communication): FS, Tenasserim Valley, Myanmar, [BMNH].

Diagnosis. The male of *Ephemera pulcherrima* Eaton can be characterised by the body length (11–12 mm), hind coxae with three blackish brown spots, abdominal terga III–VI with two pairs of longitudinal black stripes, and abdominal terga VII–IX with three pairs of longitudinal dark brown stripes (modified from Eaton 1892 and Hsu 1936–1937b).

Distribution. China (Fujian, Guangdong), Myanmar.

Remarks

Ephemera pulcherrima was described by Eaton (1892) based on the female subimaginal specimen collected from the Tenasserim Valley in Myanmar. Ulmer (1926) described the male adult of this species from specimens collected in Fujian and Guangdong, China. Both *E. annandalei* and *E. pulcherrima* are recorded in Myanmar, but they can be distinguished by their abdominal terga markings and the number of spots on their hind coxae. Ulmer (1926) and Hsu (1936–1937b) provided the figures of the male adult abdomen and genitalia of *E. pulcherrima*.

***Ephemera purpurata* Ulmer, 1919**

Ephemera purpurata Ulmer, 1919: 8 (M, MS) [Holotype: M; Kouy-Toheou, China; Type deposition: Unknown]; Hsu, 1936–1937b: 435 (M); Uéno, 1969: 234 (F); You & Gui, 1995: 107 (M).

Material. Not available.

Diagnosis. The male adult of this species (modified from Ulmer 1919) can be distinguished from other species of the genus by the combination of the following characters: body length of 13–15 mm, hind coxae with one blackish brown spot, abdominal terga III–VIII with three pairs of longitudinal black stripes, and long, slender, and apically pointed penes.

Distribution. China (Guizhou), Thailand.

Remarks

Ephemera purpurata was described by Ulmer (1919) on the basis of male adult and male subimaginal specimens collected from Kouy-Toheou in Guizhou, China, and Uéno (1969) described the female adult from specimens collected from Muang Fang, Thailand. Although Ulmer (1919) and Hsu (1936–1937b) recorded that the holotype specimen is deposited in the Paris Museum, we were unable to confirm the type preservation. This species can be distinctly characterised by its long, slender, and apically pointed penes. Ulmer (1919) and Hsu (1936–1937b) provided the figures of the male adult abdomen and genitalia.

Ephemera quadriguttata* Lestage, *nomen dubium

Ephemera quadriguttata Lestage, 1927: 93 (M) [Type: M; Cho-Ganh, Tonkin; Type deposition: unknown].

Material. Not available.

Distribution. Tonkin.

Remarks

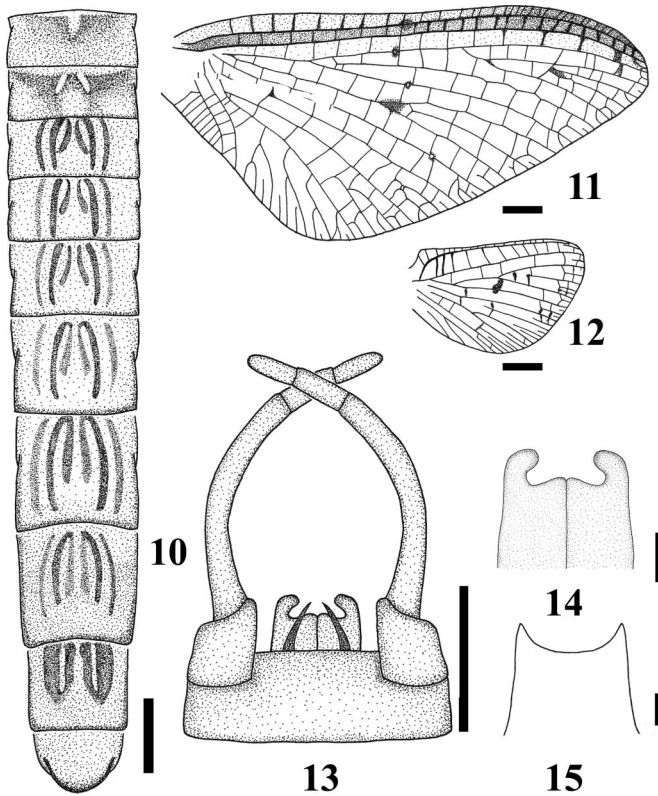
Ephemera quadriguttata was initially described by Lestage (1927) on the basis of the male adult specimen collected from Hanoi, Vietnam. Lestage's (1927) original description, however, does not contain characters by which the identification of this species can be verified nor does it specify the depository of the type specimen. Currently, few natural habitats for *Ephemera* larvae exist in the Hanoi area, as the result of urbanisation (V.V. Nguyen, personal communication).

***Ephemera rufomaculata* Zhou & Zheng, 2003 (Figures 10–15)**

Ephemera rufomaculata Zhou & Zheng, 2003: 666 (M, F, L) [Holotype: M, Mengxing, Mengla County, China; Type deposition: NJNU].

Material. 10 M, 22 F & 2 L: Loei R., Loei Pro., Phu leong, Ban Non Pattana, Thailand, 19-I-2006, T. Nisarath, S. Supalak, B. Boonsatien & K. Paiiboon, [SWU-AIC].

Diagnosis. The male adult of *E. rufomaculata* can be distinguished from other species of the genus by the combination of the following characters: Hind coxae with one spot,



Figures 10–15. *Ephemera rufomaculata*, male adult: (10) abdomen; (11) forewing; (12) hind wing (13) genitalia; (14) penis. Larva: (15) frontal process. Scale bars = 1 mm (10, 11, 12, 13), 0.1 mm (14, 15).

forewings (Figure 11) and hind wings (Figure 12) with dark brown markings, adominal terga III–IX (Figure 10) with three pairs of longitudinal chestnut brown stripes (stripes on tergum IX broadened and fused), and blunt apex of penes (Figures 13, 14). The larva of *E. rufomaculata* can be distinguished by the relatively shallow concavity of the head frontal process (Figure 15).

Male adult. Abdominal terga, forewings and hind wings, and genitalia are illustrated in Figures 10–14. Detailed description of the adults was provided by Zhou and Zheng (2003).

Mature larva. Body length 7.8–9.8 mm; caudal filaments 2.3–2.5 mm.

Head. Compound eyes black. Antennae pedicel with two heavily stout setae ventrally near distal margin; flagella with well-developed whorls of hairlike setae. Head frontal process (Figure 15) concave; lateral margins straight; margin of concavity relatively shallow and dorsally with long setae. Labrum distal margin emarginated. Mandibular tusks well-developed. Maxillary palpi three-segmented. Labial palpi three-segmented.

Thorax. Pronotum pale yellow, with dense setae on anterior and lateral margins. Mesonotum and metanotum pale yellow.

Abdomen. Abdomen yellowish brown, with brown markings; tergum I anteromedially yellowish brown; tergum II with one pair of yellowish brown oblique spots anteromedially and dark brown round spots laterally; terga III–IX with three pairs of longitudinal chestnut brown stripes; stripes on tergum IX broadened and fused; terga II–IX with dark spots at lateral edges; tergum X posterior margins dark brown. Abdominal sterna yellowish brown, sterna II–IX with one pair of chestnut brown longitudinal stripes; stripes on sternum IX relatively broad. Caudal filaments with row of lateral hair-like setae.

Distribution. China (Yunnan, Guizhou), Thailand.

Remarks

Ephemera rufomaculata was described by Zhou and Zheng (2003) on the basis of the male and female adult and larval specimens collected from southern China, but the larva was poorly described. We herein re-describe the larva of this species using fresh material collected from Thailand.

Uéno (1969) recorded the male adult of *E. javana* Navás from specimens collected in northern Thailand. Judging from the description, e.g. wing markings, and distributional data, Uéno's male adult specimen most probably belongs to *E. rufomaculata*.

Ephemera sauteri Ulmer, 1912

Ephemera sauteri Ulmer, 1912: 369 (M, F) [Syntypes: M, F; Kosempo, Taiwan; Type deposition: ZSI]; Hsu, 1936–1937b: 436 (M, F); Hubbard & Srivastava, 1984: 2 (type information); Kang & Yang, 1994: 396 (L).

Material. Syntypes: M, ZSI no. 65/H8 (pinned) and ♀ type, ZSI no. 66/H8 (pinned), Kosempo, Formosa (Taiwan), [ZSI] (based on Hubbard & Srivastava 1984).

Diagnosis. The adult of *E. sauteri* Ulmer can be distinguished from other species of the genus by the combination of the following characters: body size of 18–21 mm, forewings and hind wings without markings, and abdominal terga VI–IX with three pairs of longitudinal black stripes (modified from Ulmer 1912 and Hsu 1936–1937b).

Distribution: China (Guangdong, Taiwan).

Remarks

Ephemera sauteri Ulmer was originally described by Ulmer (1912) from Taiwan on the basis of male and female adult specimens. Hsu (1936–1937b) reported this species from Guangdong, China. These type specimens and other specimens are deposited at the ZSI (Hubbard and Srivastava 1984) and the DEI (Ulmer 1912). Kang and Yang (1994) described the larval stage of this species from Taiwan and the larval material was deposited at the National Chung Hsing University (NCHU) in Taichung, Taiwan. This species inhabits high mountain streams at altitudes of over 2000 m (Kang and Yang 1994).

Ephemera serica Eaton

Ephemera serica Eaton, 1871: 75 (M, F, FS) [Syntypes: M, F; Northern China; Type deposition: BMNH]; Eaton, 1883: 73 (M, F, FS; China, Hong Kong); Ulmer, 1926: 89 (M, F, MS, FS; Tonkin);

Hsu, 1936–1937b: 438 (M, F, FS; Northern China, Hong Kong, Guangdong); Kimmins, 1960: 309 (Lectotype designation).

Material. Lectotype: Hong Kong 61-49, [BMNH]; allotype: Northern China, [BMNH] (based on Kimmins, 1960 and D. Goodger, personal communication).

Diagnosis. The adult of *E. serica* Eaton can be distinguished from other species of the genus by the combination of the following characters: body size of 11–15 mm, all coxae with one black spot, and abdominal terga III–IX with one pair of longitudinal black stripes (modified from Eaton 1871, 1883; Ulmer 1926; Hsu 1936–1937b).

Distribution. Southern China (Hong Kong, Guangdong), peninsular Southeast Asia (Tonkin).

Remarks

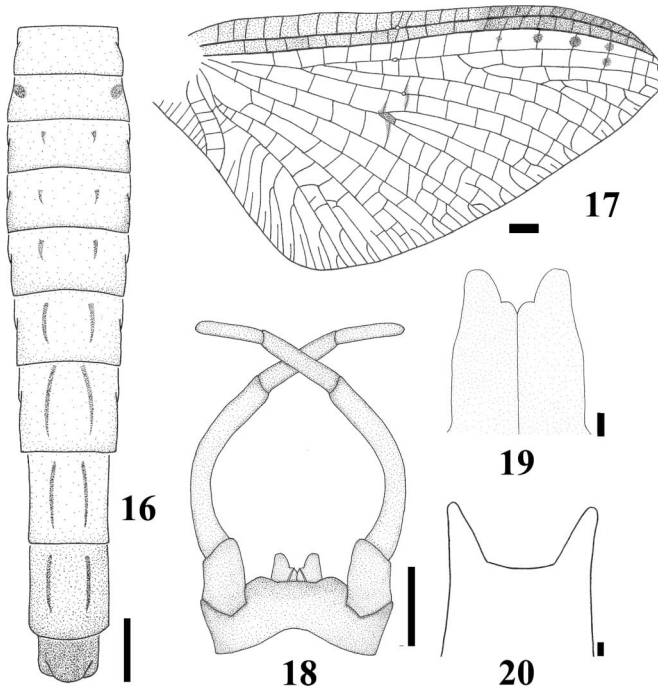
Ephemera serica Eaton was initially described by Eaton (1871) on the basis of male and female adult specimens collected in northern China, and Ulmer (1926) also reported this species in the Tonkin area. Although Eaton (1871), in his original description, indicated that the type locality of *E. serica* is northern China, Eaton (1883) added the locality Hong Kong when he re-described the male and female adults and female subimago using probably the same material as that of his former original description. Hsu (1936–1937b) assigned the male and female adults from northern China as holotype and allotype, respectively, and other adult and subimaginal specimens from Hong Kong and Kwangtung (=Guangdong), China, as paratypes, but the figures of male and female abdomen and male genitalia used in his description were copied from Ulmer (1926), which was based on specimens from the Tonkin area. Kimmins (1960) later designated the lectotype of this species using the male adult specimen from Hong Kong, and the lectoallotype (female adult) from northern China. On the basis of our distributional data regarding the *Ephemera* species (Hwang et al. 2007), no *Ephemera* species that possess paired striped abdominal markings and genital structure as in *E. serica* are currently distributed in Northeast Asia, including northern China. It is thus very possible that the syntype specimens of *E. serica* collected from northern China and Hong Kong are not of the same species. Despite this situation, we adopt Kimmins' lectotype designation and recognise that *E. serica* is distributed throughout the southern areas of China (Hong Kong, Guangdong) and peninsular Southeast Asia (Tonkin).

The lectotype specimen is preserved at the BMNH, but the head and thorax were destroyed by pests (D. Goodger, personal communication). Ulmer (1926) and Hsu (1936–1937b) provided the figures of the male and female adult abdomen and male genitalia. Kimmins (1960) also provided the figures of the male adult genitalia.

***Ephemera spilosa* Navás, 1936** (Figures 16–20)

Ephemera spilosa Navás, 1936:117 (M, F) [Holotype: M; Kuling, Kiangsi (= Jiangxi) Prov., China; Museum of Heude, Shanghai; type destroyed]; Hsu, 1937–1938:53 (M, F); Gui, 1985:95 (catalogue); Zhang et al., 1995:75 (list).

Material. Vietnam: 1 M (penes, forewings, and hind wings dissected), 5 MS, 2 FS & 5 L: Thac Bac (2000 m), Sa Pa County, Lao Cai Prov., 22-IV-2002, V.V. Ngyuen & D.H. Hoang, 2 MS, 2 FS &



Figures 16–20. *Ephemera spilosa*, male adult: (16) abdomen; (17) forewing; (18) genitalia; (19) penis. Larva: (20) frontal process. Scale bars = 1 mm (16, 17, 18), 0.1 mm (19, 20).

4 L: Cat Cat (1400 m), Sa Pa County, Muong Hoa Ho R., Lao Cai Prov., 23-IV-2002, V.V. Nguyen & D.H. Hoang, [SWU-AIC].

Diagnosis. The male adult of *E. spilosa* Navás can be characterised by the combination of the following characters: hind coxae with one blackish spot, hind wings without dark brown markings, abdominal terga (Figure 16) III–IX with one pair of longitudinal dark brown stripes, long and slender forceps, and apically blunt penes (Figures 18, 19).

Male adult. Body length 15.7 mm, caudal filaments 42.6 mm. Body colour brown with various chestnut brown markings.

Head. Compound eyes dorsal part light grey and ventral part grey in alcohol. Ocelli dorsal half white and basal half dark brown to black. Antennae basal segment basally light yellow and apically dark brown; flagellum yellowish brown.

Thorax. Pronotum brown with one pair of short chestnut brown stripes. Mesonotum chestnut brown. Metanotum marginally chestnut brown. Forelegs brown; femora, tibiae and tarsi darker at joints; femur 2.57 mm, tibia 5.52 mm, and tarsus 8.47 mm (segments 1, 2, 3, and 4 3.42 mm, 2.58 mm, 1.73 mm, and 0.74 mm, respectively); claws similar. Mid legs and hind legs pale yellow; hind coxae with one blackish spot; claws dissimilar. Forewings (Figure 17) 8.5 mm in length, 16.7 mm in width; membrane hyaline with

chestnut brown spots; apical area between R_1 and R_2 with several chestnut brown round spots. Hind wings 3.9 mm in length, 6.7 mm in width, without dark brown markings.

Abdomen. Abdominal terga (Figure 16) light yellow, with brown to dark brown markings; tergum I without markings; tergum II with one pair of dark brown round spots laterally; terga III–IX with one pair of longitudinal dark brown stripes; terga II–IX with dark spots at lateral margins. Abdominal sterna light yellow; sterna II–IX with one pair of chestnut brown longitudinal stripes; stripes on sternum IX relatively broad.

Genitalia (Figure 18). Genital forceps dark brown, four-segmented, slender, and long; subgenital plate slightly concave; penes (Figure 19) apically blunt. Caudal filaments brown, with darker annulations at articulations (annulations terminally lighter).

Female subimago. Body length 20.1–20.3 mm (caudal filaments broken). Markings similar to male adult.

Mature larva. Body length 18.1–24.2 mm; caudal filaments 5.4–7.3 mm.

Head. Compound eyes black. Pedicel of antennae ventroapically with two heavily stout setae; flagella with well-developed whorls of hairlike setae. Head frontal process (Figure 20) deeply concave; lateral margins straight; margin of concavity dorsally with irregular long setae. Labrum distal margin emarginated. Mandibular tusks well developed. Maxillary palpi three-segmented; segment 2 and 3 with long setae. Labial palpi three-segmented; segment 3 with stout setae.

Thorax. Pronotum brown, with dense setae on anterolateral and lateral margins. Mesonotum brown. Legs yellowish brown; hind coxae with one blackish spot.

Abdomen. Abdomen light yellow, with brown markings; terga colour pattern similar to adult. Caudal filaments with row of lateral hair-like setae.

Distribution. China (Hong Kong, Guangdong, Jiangxi), northern Vietnam (Lao Cai Prov.).

Remarks

Ephemera spilosa was described by Navás (1936) on the basis of the male and female adult specimens collected from Kiangsi (=Jiangxi Province) and Hsu (1937–1938) redescribed this species using Navás' specimens. The type specimens were destroyed during the war in the 1940s (X. Tong, personal communication). We describe the larval stage for the first time in this study using material obtained from Vietnam. This species is similar to *E. serica* in terms of its abdominal markings (one pair of stripes), but they are distinguished from each other by the number of spots on the coxae: *E. spilosa* has one spot only on the hind coxae, whereas *E. serica* has one spot on all coxae. The larvae of *E. spilosa* were found in mountain streams of the Sa Pa Highland area in northern Vietnam. *Ephemera spilosa* is common and widespread in Hong Kong and Guangdong areas in southern China. Navás (1936) and Hsu (1937–1938) provided the figures of the male adult abdomen of *E. spilosa*.

Table 2. Character distribution of the tropical Southeast Asian *Ephemera* species mainly based on known bibliographic sources.

No	Species	Known stage	Abdominal terga II-VI stripes	Abdominal terga VII-IX stripes	Adult coxal markings	Forewing markings	Hind wing markings	Male genitalia	Remarks
1	<i>E. amandalei</i>	M, MS, F	3 pairs	3 pairs	hind coxae with 1 spot	4 markings	?	penes short and triangular with apices very slightly rounded	valid
2	<i>E. duponti</i>	M, F, MS, FS	3 pairs	2 pairs	?	markings present	2-3 markings	forceps long, penes quadrangular and rounded at top	valid
3	<i>E. exspectans</i>	M, FS	2 pairs	2 pairs	?	?	?	forceps and penes grayish brown, basal segments of forceps darker	valid
4	<i>E. formosana</i>	M, F, MS, FS, L	terga III-IV: 1 pair terga V-VI: 2 pairs	3 pairs	hind coxae with 1 spot	markings absent	markings present	?	valid
5	<i>E. hainanensis</i>	M, MS, F, L	terga II-V: 1 pair tergum VI: 2 pairs	2 pairs	hind coxae with 3 spots	3-4 round markings	markings absent	penes U-shaped in median margin, apically blunt	valid
6	<i>E. innotata</i>	M	?	?	?	?	?	?	<i>nomen dubium</i>
7	<i>E. javana</i>	M, F	terga III-VI: 3 pairs	3 pairs	hind coxae with 1 spot	markings present	markings present	?	<i>nomen dubium</i>
8	<i>E. longiventris</i>	F	?	?	?	markings present	?	?	<i>nomen dubium</i>
9	<i>E. mcaffertyi</i>	M, F	terga III-VI: 2 pairs	3 pairs	hind coxae with 2 spots	markings absent	markings absent	penes notched medially, apically blunt	valid
10	<i>E. pulcherrima</i>	M, F, FS	terga III-VI: 2 pairs	terga VII-IX: 3 pairs	hind coxae with 3 spots	small markings present	markings absent	penes short, fused, flat, and normal form	valid
11	<i>E. purpurata</i>	M, MS, F	terga III-VI: 3 pairs	terga VII-VI: 3 pairs	hind coxae with 1 spot	markings present	dark purple markings present	penes long and narrow, fused at base, sharply pointed at spear shaped tip	valid
12	<i>E. quadriguttata</i>	M	?	?	?	?	?	?	<i>nomen dubium</i>
13	<i>E. rufomaculata</i>	M, F, L	tergum II: 1 pair	terga III-IX: 3 pairs	hind coxae with 1 spot	markings present	markings present	Penes basally fused and apically with small process bent dorsomedially	valid
14	<i>E. sauteri</i>	M, F, FS, L	terga VI: 3 pairs	terga VII-IX: 3 pairs	hind coxae with 1 spot	markings absent	markings absent	?	valid
15	<i>E. serica</i>	M, MS, F, FS	terga III-VI: 1 pair	terga VII-IX: 1 pair	all coxae with 1 spot	markings present	markings absent	penes short and broad, widely separated	valid
16	<i>E. spilosa</i>	M, F, L	terga III-VI: 1 pair	terga VII-IX: 1 pair	hind coxae with 1 spot	markings present	markings absent	apex of penes blunt	valid

Key to the Southeast Asian adult males of *Ephemera* (see also Table 2)

1. Abdominal terga III–IX with one pair of longitudinal dark brown stripes (Figure 16)..... 2
 - Abdominal terga III–IX with two or three pairs of longitudinal dark brown stripes (Figures 1, 6, 10) 3
2. All coxae with one blackish spot *E. serica*
 - Only hind coxae with one blackish spot *E. pilosa*
3. Abdominal terga VII–IX with two pairs of longitudinal dark brown stripes (Figure 1) 4
 - Abdominal terga VII–IX with three pairs of longitudinal dark brown stripes (Figures 6, 10) 6
4. Abdominal terga II–V with two pairs of longitudinal dark brown stripes *E. exspectans*
 - Abdominal terga II–V with one pair of longitudinal dark brown stripes 5
5. Hind wings without markings *E. hainanensis*
 - Hind wings with 2–3 markings *E. duporti*
6. Hind coxae with two or three spots 7
 - Hind coxae with one spot 8
7. Hind coxae with two spots; wings without markings (Figure 7) *E. mccaffertyi*
 - Hind coxae with three spots; forewings with small markings *E. pulcherrima*
8. Forewings without markings 9
 - Forewings with markings 10
9. Abdominal terga III–IV with one pair of longitudinal dark brown stripes *E. formosana*
 - Abdominal terga III–IV with three pairs of longitudinal dark brown stripes *E. sauteri*
10. Penes greatly elongated and apically pointed *E. purpurata*
 - Penes relatively short 11
11. Penes short and triangular, apically slightly rounded *E. annandalei*
 - Penes basally fused and apically with small process bent dorsomedially (Figures 13, 14) *E. rufomaculata*

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